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SEISMIC SAFETY ELEMENT

THOUSAND OAKS GENERAL PLAN

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F. Beach Leighton & Associates Inc. *Environmental Earth Sciences and Geotechnical Engineering*

Project G4046

CITY OF THOUSAND OAKS

SEISMIC SAFETY ELEMENT - PART 1

SEPTEMBER 6, 1974

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INTRODUCTION

General Overview, Related Elements and Legislation

The Seismic Safety Element, required by state law in 1971 as part of the general plans for all cities and counties in California (Government Code, Section 65302f) embodies the principal geotechnical component of land use planning. Although its basic objective is to reduce loss of life, injury, damage to property, and economic and social dislocation resulting from future earthquakes, it also is concerned with slope stability problems (such as landslides and mudslides) and other soil-related hazards. Seismic hazards specifically to be identified and evaluated include susceptibility to surface rupturing from fault movement, ground shaking, related ground failure, and to seismically induced waves (tsunamis or seiches). Additionally, for the Thousand Oaks General Plan study, the soil-related characteristics of shrink-swell potential, erosion susceptibility, percolation capability, subsidence and hydrocompaction are evaluated as to their land use implications.

The Safety Element, among other issues, (such as fire prevention and control, and flood hazards) is concerned with geotechnical hazards generally, including their identification, mapping and evaluation. Although seismic hazards are considered, the principal geologic hazards addressed in the Safety Element are related to slope instability and soil problems; and how they can be avoided or minimized in the planning process. The Seismic Safety Element document contains all of the basic geotechnical data and evaluation for the Safety Element. The Open Space and Conservation Elements have significant geotechnical inputs also, relating particularly to mineral and soil conservation, preservation of unique geologic features, mineral resource production, and possible open space designation for hazardous geologic conditions, if warranted.

Other state legislation related to seismic and geologic concerns include the following:

Public Resources Code

Sections 660-662 and 2621-2625; these sections require the State Geologist to delineate special studies zones encompassing potentially and recently active fault traces (Alquist-Priolo Bill).

Sections 2700-2708; require the Division of Mines and Geology to purchase and install strong motion instruments (to measure the effects of future earthquakes) in representative structures and geologic environments throughout the state.

Education Code

Section 15002.1; requires that geological and soil engineering studies be conducted on all new school sites and on existing sites where deemed necessary by the Department of General Services.

Section 15451-15466; these sections require that public schools be designed for the protection of life and property (Field Act).

Health & Safety Code

Section 15000 et seq.; require that geological and engineering studies be conducted on each new hospital or additions affecting the structure of an existing hospital.

Sections 19100-19150; require certain buildings to be constructed to resist lateral forces.

The provisions, intent and land use implications of the Alquist-Priolo Bill will be discussed in greater detail below.

REPORT SUMMARY AND GENERAL CONCLUSIONS

Geotechnical Findings

- The City of Thousand Oaks, including its sphere of influence, is in a setting of diverse geologic conditions with an equally wide range of existing and potential hazards. There are, however, significantly large areas of undeveloped land having relatively low geotechnical risk suitable for multiple land uses. Past soil problems and localized slope instabilities have been effectively controlled through the application of up-to-date building codes and development regulations.

- Levels of seismic (earthquake) shaking are expected to be generally moderate, as compared with other regions of California. The most likely (earthquake-generating) faults are identified as the San Andreas, San Fernando-Sierra Madre, Newport-Inglewood, and Malibu Coast-Santa Monica Faults. Locally significant, but regionally less important, are the following major faults within the study area: the Sycamore Canyon, Boney Mountain and Conejo.

- Ratings of seismic and geologic hazards within the study area are summarized as follows:

  <u>Seismic shaking</u> (bedrock sites)-------------Moderate

  <u>Seismic shaking</u> (valley alluvium sites)------Generally moderate; possible localized intensity amplification effects.

  <u>Fault rupture potential</u>---------------------Low in most areas; somewhat higher probability along major faults.

  <u>Liquefaction potential</u>----------------------Low to possibly moderate probability, limited to small proportion of alluvial valley areas.

Seiches, potential inundation
due to dam failure, other
secondary seismic effects--------------------Low

Slope instability----------------------------Low in west half;
moderate to locally high in east
half of study area.

Soil-related problems------------------------Locally high for
expansive soil; mostly low for other
problems.

- The existing and inventoried geotechnical data base is considered quite adequate for the purposes of the present seismic safety study. Certain aspects, however, may require more detailed investigation to verify the suitability of the more important land uses in the higher risk areas.

Impact Assessment

1. The sole geotechnical hazard identified as a probable unacceptable risk within the study area is the D-rated zone delineating the three major faults (refer to the hazards and capability maps, Plates I and II). This would primarily impact critical use or important structures (Building Type/Land Use Groups I and II on chart accompanying Plate II) proposed within the zone. Although such risk zones are not absolute restrictions for such uses, it may be difficult to meet the requirement for approval, particularly if the faults are officially classified as potentially active.

2. All other D-rated risk zones are known landslides which are not considered significant threats to existing structures, improvements, or public safety. Such hazards along with all other identified risks are considered tolerated, avoidable, or acceptable risks.

3. A comprehensive building survey and hazardous-building abatement program, in view of the apparent absence of substandard, earthquake-sensitive buildings within the study area, is considered unnecessary.

4. No substantive changes are believed necessary in the present building codes or development regulations for the City. They should be periodically reviewed and revised, if necessary, to reflect the current state of the art and the latest geotechnical data.

5. No dams, reservoirs or water tanks were identified as seismically or geotechnically unsafe. Routine monitoring of these facilities for leakage is advisable, however, on a periodic basis, particularly after earthquakes.

6. No significant negative social, ecologic, or economic impact on the general community is expected from the implementation of the seismic safety, safety or other related elements with geotechnical inputs. In the long-term, they should have very positive impacts.

STATEMENT OF GOALS AND PUBLIC POLICY

Goals

Goals of the Seismic Safety and Safety Element provide a link between the identified problems and issues, and the policies and implementation measures which follow. They provide basic guidelines for City decisions related to geotechnical hazards and assets, as they affect land-use planning and development standards. The following are recommended major goals for adoption:

- To protect life, property and public well being from seismic and other geologic hazards.
- To reduce or avoid adverse economic, social, and environmental impacts caused by geologic conditions.

Policy

These policies provide a general direction or more specific steps for achieving the stated goals, through implementation and action programs. The following are recommended policy statements:

- To maintain, revise (whenever necessary), and enforce existing standards and criteria to reduce or avoid all levels of seismic or other geologic risk, whether it be unacceptable, tolerated, or avoidable risk.
- To evaluate the compatibility of existing zoning as well as future land use allocation, with known geologic risk zones, or those which may be identified in the future.
- To recognize the need to provide greater safety for important or critical-use structures (such as hospitals, schools, public assembly facilities, dams and utility corridors) through careful site selection, appropriately comprehensive site investigation and enforcement of applicable codes and regulations.

- To prohibit development of important or critical-use structures in any active or potentially active fault zones, unless no other more suitable site can be located, and the site is shown to be safe for the intended use.

- To advocate improved seismic safety programs for schools and promote greater general public awareness of all types of geotechnical hazards.

- To improve interjurisdictional cooperation and communication, especially in regard to seismic safety aspects related to dams, reservoirs, state highway and freeway structures, regional fault studies, legislative matters, and disaster response or emergency plans.

- To advocate improved earthquake insurance programs and seek qualification of the City for Federal mudslide insurance.

Risk Definition and Risk Mitigation

In order to evaluate the adequacy of existing codes, regulations or practices used to reduce or avoid seismic and other geologic hazards, it is necessary to relate and define relative risk levels with specific hazards. The several types of risks discussed and defined, for the purposes of this report, include acceptable, unacceptable, avoidable, and tolerated risk.

Unacceptable Risk: Geologic hazards in this category include those which pose the most serious threat to life, property or an existing structure, where no permitting or effective regulatory control exists to require abatement of the hazard. An example of such an unacceptable risk might be an old, earthquake-vulnerable hospital located on an active fault. A well-constructed one-story wood frame residence located in an active fault zone but not on a fault trace, on the other hand, would be a less severe risk and also categorized as unacceptable, or perhaps tolerated, depending on the dictates of public policy.

In the case of the most severe slope stability problems, a prime example of an unacceptable risk might be an impending landslide about to bury an existing house or other habitable structure for which there is no regulatory control to prohibit its occupancy. For the most part such hazards are avoidable risks which can and should be mitigated in the planning or construction stages of development, either by prohibiting construction within the slide (or fault zone) or eliminating the risk by corrective grading or other stabilization measures which may be feasible.

Tolerated and Acceptable Risk: Between the extremes of the risk scale, unacceptable at one end and acceptable at the other, there are all degrees of relative risk. These are less clear-cut situations such as a suspected slide (or potentially active fault) which may or could pose a threat to existing features or improvements. A similar situation is the possible hazard of slide-prone formation which underlies a site. Although these may be equally unacceptable risks, such factors as the probability of occurrence at a site, and the importance or value of a structure or land use, result in gradation in the degree of risk unacceptability. Also, further toward the acceptable risk and end of the scale are other presently unrecognized hazards, either because of the lack of information or capability to detect the hazard. Although there appears to be no consensus for the definition of acceptable risk (for the purposes of categorizing the various geotechnical hazards in land-use planning), those considered most unacceptable can be identified and mitigated if possible, or restricted from future use. Those remaining risks, therefore, are placed in the category of tolerated or acceptable risk, without any rigid distinction between the two necessary.

Criteria For Decision-Making Related To Risk: The following factors should be considered in evaluating risk.

1. Severity of potential losses: Seismic or other geologic impacts including loss of life, injury, property damage, loss of function and hidden cost should be considered.

2. Risk reduction capabilities: Consideration should be given to current technological capabilities, available fiscal and manpower resources, and established priorities.

3. Probability of loss: The probability of future seismic or other adverse geologic occurrences should be evaluated in light of their possible effect on structures or human activities.

4. Adequacy of basic data: This is an important factor in estimating the probability of imperceived hazards.

For the most part, there must be reliance upon only very general, qualitative appraisals of these factors, considering the present study scope.

IMPLEMENTATION PROGRAMS

The implementation aspects of any plan are as vital to accomplishing the primary aims, as are the identification of hazards and the statement of policies. Following is an integrated set of recommended actions relating to existing programs which may have application and strategy options, major land use concerns, and specific land use planning and development control implications.

Existing Programs

The following programs have actual or potential application to the problems identified in this element:

City

- Zoning, Building and Grading Regulations
- Thousand Oaks Development Plan, 1970

County

- Ventura County Seismic and Safety Element (in progress)
- Zoning and Building Regulations (pertinent to Thousand Oaks sphere of influence)
- Cooperative Mapping Program with California Division of Mines and Geology and U. S. Geological Survey

State

- Dam Inundation Areas Mapping & Evacuation Plans
- Dam Safety Inspection
- Active Fault Mapping (Alquist-Priolo Hazards Zone Act)
- General Geologic Mapping
- School Safety

Federal and Other

- U. S. Geological Survey Mapping and Earthquake Research and Monitoring
- Dept. of Housing and Urban Development - Urban Planning Research Funding
- University Research on Geologic Hazards

Hazard Reduction Strategies

Methods of mitigating geologic hazards most often employed fall into three basic categories, as follows:

Hazard Abatement: This is the most positive means of hazard reduction but also is the most controversial since it primarily involves the elimination of an existing hazard, usually at a substantial cost to the owner. Demolition of an old, earthquake-vulnerable building is an example. It can also have significant negative social impact related to possible relocation requirements of the abatement.

Impact Reduction: This strategy addresses measures to minimize the adverse effects of future earthquakes and geologic events on existing and future developments. It can involve reactive efforts such as emergency or contingency plans after a disaster; or standards up-grading to minimize possible adverse effects.

Hazard Avoidance: Most important at the land use planning level is the strategy of avoidance. With the advanced knowledge of the various types and severity of hazard within a planning area, those land uses most compatible with the risk can be matched, thereby avoiding unacceptable risk areas or limiting them to the least important land uses.

Setting Priorities

The following criteria should be used to establish priorities so that judgments can be made regarding allocation of limited funds to the most critical areas or problems:

1. Significant and impending threats to human life or safety.
2. Unacceptable levels of potential economic loss.
3. Potential for widespread social disruption.
4. Significant threats to future populations or development.
5. Problems which are not likely to result in adverse impacts.

Major Assets, Problems and Issues

Positive aspects of the study area to be balanced against the problems and hazards include the following assets.

Assets:

1. An apparent abundance of undeveloped land without significant constraints to multiple land uses.
2. A comparatively high level of geologic and seismic hazard awareness on the part of citizens and public officials.
3. Continuing programs to further reduce geologic hazards through research and code up-grading.

Problems and Issues: Protection of Existing Population and Development

1. Earthquake Hazardous Old Buildings. None has been identified in the City. Therefore, building abatement due to seismic concerns is not considered necessary at this time. Any building inspection procedure to verify compliance with current codes (e.g. building, electrical, plumbing, etc.), however, should also be cognizant of possible structural deficiencies related to seismic resistance, so that such buildings can be identified for additional evaluation.

2. Existing Structures or Improvements Within Fault Zones Tentatively Classified Potentially Active. Because the probability of fault activity is presently believed to be very low, no abatement measures are considered necessary. All property owners within the zones, however, should be made aware of the potential hazard and its implications.

3. Medium and High-Rise Structures. Particular seismic problems related to the safety of medium-rise (4 to 6 stories) and high-rise (7 or more stories) buildings involve emergency response difficulties, namely evacuation procedures and fire control. This does not appear to be a major problem in the City, due to the limited number of medium-rise buildings, (none are in the high-rise category). Nevertheless, the existing medium-rise buildings should be reviewed with these considerations in mind. No special seismic concerns related to low-rise buildings (1 to 3 stories) have been recognized.

4. Dam, Reservoir and Water Tank Safety. None of the facilities in this category within the study area have been identified as seismically unsafe or a significant hazard to adjoining areas. Cooperation and communication with the agency controlling these facilities, however, is recommended so that their current status can be monitored.

5. Vital Facilities. These include fire control, law enforcement, hospitals and communication centers which must remain operational following a major earthquake. Fortunately, no buildings of this category lie within the high risk zones of the study area. Although individual sites or facilities were not specifically evaluated for the present study, further investigation regarding their compliance with current structural standards for aseismic design should be considered, to verify their apparent safety.

6. Schools. The 1933 Field Act established minimum earthquake safety standards for school construction. Legislation passed in 1968 and recently modified prohibits the use of seismically hazardous school facilities after 1977. It is our understanding that all of the public schools within the study area comply with the Field Act. Several school sites, however, are at least partially within the fault zone tentatively classified potentially active (D-risk zone shown on Plate II) in the area of Borchard Road south of Lesser Drive (a high school); and in the area north of Gainsborough Road near Hendrix Avenue (an elementary, intermediate and private school). Although these do not justify abatement measures at this time, the Boards of the respective schools should be notified of the potential hazard and its implications. Any proposal for new construction at these sites may require special investigation of the fault hazard.

Problems and Issues: Management of Future Development.

1. Seismic Design Considerations - All Construction. Conformance with the 1973 Uniform Building Code is considered adequate for most ordinary types of construction (Groups IV and V on the chart included with Plate II of this report), utilizing the seismic parameters given in Table 4. At the discretion of the Building Official, certain of the more important or critical use structures in Groups I, II and III (such as hospitals, schools, high-occupancy structures or public assembly facilities, high-rise buildings and fire stations, etc.) should be specified as requiring more conservative seismic design parameters, utilizing the maximum credible earthquake (rather than the maximum probable earthquake). Other, less important uses in Groups I, II and III (such as certain utilities, roads, and small isolated dams) could be designed utilizing the maximum probable earthquake, as are the ordinary types of construction in Groups IV and V.

   Determination of the seismic design parameters for the maximum credible earthquake will require independently derived data based on specific site conditions and the type of construction proposed. A design response spectrum or criteria set forth in the Uniform Building Code (as supplemented by the April 1974 recommended revisions) should be required as a basis for aseismic design. The latest U.B.C. criteria provide for importance factors (for various building types) to be applied in the design. Inclusion of these factors should be required if the U.B.C. is utilized for design.

   In certain cases, it may be appropriate for the Building Official to consider allowance for local variations in site conditions by permitting adjustment of the "Z" factor, based on specific site data. The "Z" factor, which is a

numerical coefficient corresponding to the seismic zone (1, 2 or 3, as delineated in the U.B.C.), is part of the formula determining the minimum total lateral seismic force for design of structures. Thousand Oaks, as well as the remainder of California, is within Zone 3, representing the highest seismic risk nationally. Because the seismic setting of the Thousand Oaks area is significantly more favorable than some other seismically active areas in Zone 3, a reduction of the coefficient (below the 1.0 required in Zone 3) is probably justified. Additional detailed geologic, seismologic, and structural engineering study of the feasibility of permitting code variances for local seismic conditions, however, will be necessary. This would require regional studies correlating the differences in seismic conditions within the zone, and as compared with a particular site being investigated.

2. Adequacy of Existing Building, Grading and Development Regulations. The existing regulations governing future construction and development are considered adequate for the mitigation of the anticipated geologic hazards. One seismic consideration possibly deserving further analysis is in regard to the safety factor required for design of buttress fills (Sec. 7-3.22d of the Grading Ordinance). Current state-of-the-art practice (observed by some southern California governing agencies) require that the seismic forces be included in stability analyses, which permit safety factors less than 1.50, but generally greater than 1.10. Considering the seismic and geologic setting of the study area, it is recommended that further study of this aspect be made before instituting a code change.

3. Geotechnical Investigation Standards. The table on Plate III of this document is intended to serve as a guide for the City Engineer or Building Official in determining

the type and scope of investigation to be required prior to the issuance of permits. The table facilitates identification of specific conems or hazards which may require particular attention in the investigation. Suggested guidelines for geologic/seismic investigations and reports are contained in various local governing agency regulations and professional society publications (e.g., Association of Engineering Geologists).

4. Liquefaction and Fault Rupture Hazards. Based on present data, specific analyses of the liquefaction hazard appears warranted only for residential tract development, high-cost facilities, and important or critical use structures (Groups I, II and III), located in the delineated possible liquefaction potential zones. As yet, the major faults tentatively classified as potentially active, do not come under the jurisdiction of the State Alquist-Priolo Act provisions, which determine investigation standards and setback requirements. At the discretion of the Building Official, all development (or only certain of the more important land uses) within the tentatively classified potentially active fault zones (the Sycamore Canyon, Boney Mountain and Conejo Faults) may be required to comply with the State requirements for the evaluation of the fault rupture hazard. The State criteria prohibit construction of habitable structures across such potentially active faults (or multiple fault lines within the zone) and require a minimum setback of 50 feet from such faults, unless specifically approved by a registered geologist.

   Future studies of the regional fault hazard, by various governmental agencies or private consultants, may require revision of the delineated special study zones (either enlarging, reducing, or even eliminating all or part of them).

GEOTECHNICAL REPORT - PART 2

INTRODUCTION

Authorization and Scope of Investigation

As authorized by the City of Thousand Oaks, under Agreement No. 358, approved on May 14, 1974, we have prepared the Seismic Safety Element of the General Plan and have provided the geotechnical input for the Safety Element. This report was prepared in accordance with the latest State guidelines (issued by the Council on Intergovernmental Relations, dated September 20, 1973) and includes the following study scope:

1. A comprehensive inventory and review of pertinent earth-science data, primarily from published reports and case histories in our files.

2. Interviews and personal communication with representatives of City, County, State and Federal agencies regarding problem areas, and status of other current related studies being conducted at various levels of government.

3. Stereoscopic study of time-lapse aerial photographs of the City and surrounding areas (between 1928 and 1968), from the Fairchild collection and other sources.

4. General field reconnaissance and inspection of problem areas.

5. Analysis of soil and groundwater data from numerous boring logs.

6. Evaluation of seismic, slope stability and other geotechnical hazards as they affect existing and future development.

7. Preparation of a Geotechnical Hazards Map, and a Land Use Capability Map, among other illustrations, to graphically portray the site conditions and facilitate their correlation with land use planning.

8. Preparation of the Seismic Safety Element document setting forth recommended seismic safety goals, aims and policy statements with the intent to reduce or minimize geologic risks; provide implementation guidelines to carry out the stated goals.

Description of Study Area, Regional Setting

The study area, comprised of approximately 60 square miles, encompassing the City limits and its sphere of influence, is located in the southeast portion of Ventura County. Refer to Vicinity Map, Figure 1. Situated in a physiographically diverse terrain, the area is centered about an upland valley (Conejo Valley) surrounded generally by east-west trending mountain ranges: the Santa Monica Mountains (on the south) and portions of the Simi Hills (on the north and east). Drainage is primarily northward and westward along Arroyo Conejo, or eastward and southward along Triunfo Canyon in the Westlake area.

Neighboring communities of Thousand Oaks include Camarillo (west), Moorpark (north), Simi Valley (northeast), and Agoura (southeast).

Development History, Cultural Aspects

Since incorporation in 1964, the City of Thousand Oaks has grown to a current population of approximately 55,700 (70,000 within the planning area). The City had its beginnings in about 1875, consisting of large ranches, and later the small community of Newbury Park. Highway improvements, including the Ventura Freeway in 1958, brought about dramatic growth and rapid development.

For the most part development, primarily for housing, has been in the valley bottoms and within the lower adjoining foothills. Commercial development has been along U.S. 101, Thousand Oaks Boulevard and Moorpark Road. Today, roughly 35 to 40 percent of the study area remains undeveloped.

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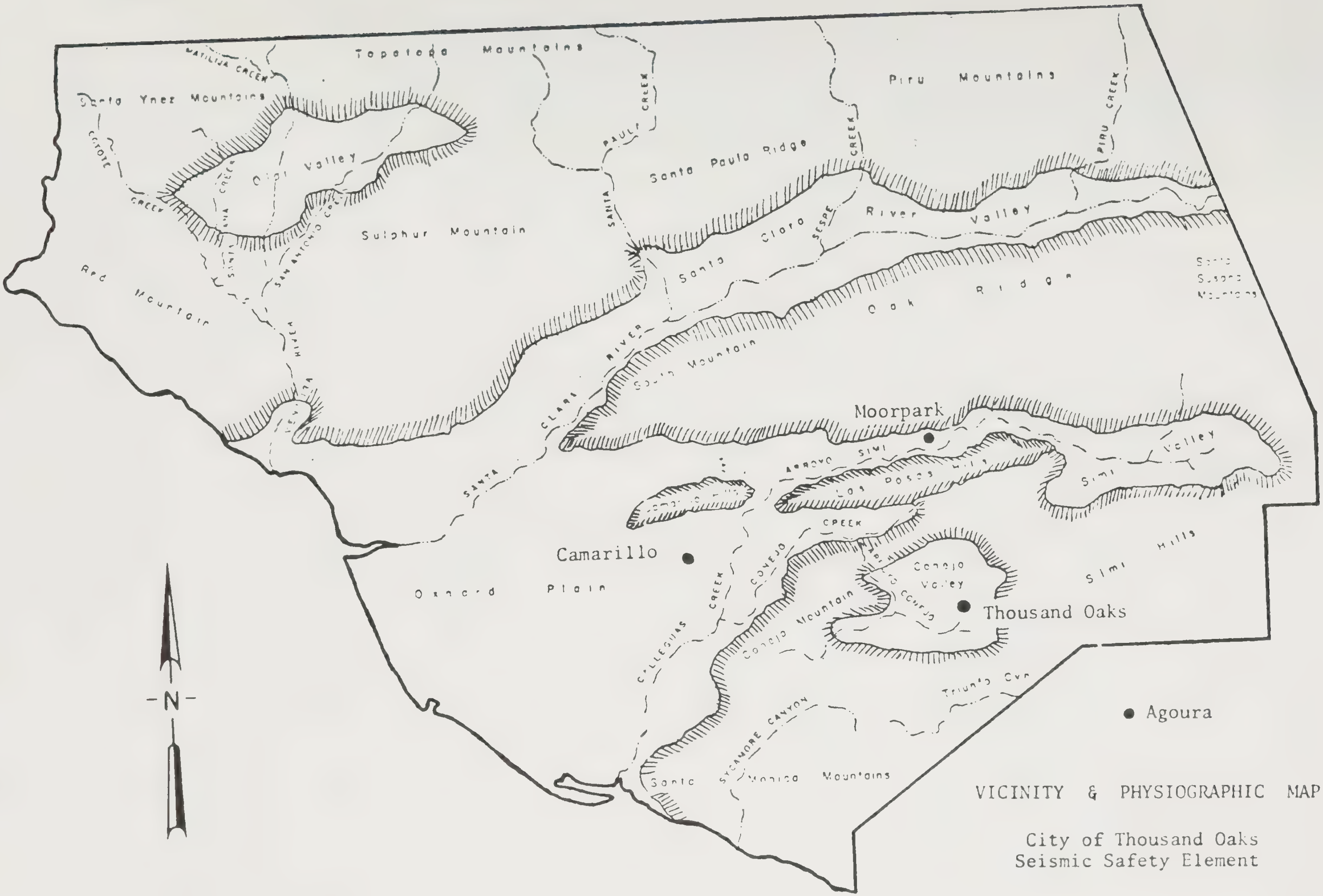


Scale: 1"=5.2 miles

VICINITY & PHYSIOGRAPHIC MAP

City of Thousand Oaks
Seismic Safety Element

FIGURE 1

REGIONAL GEOLOGIC STRUCTURE AND HISTORY

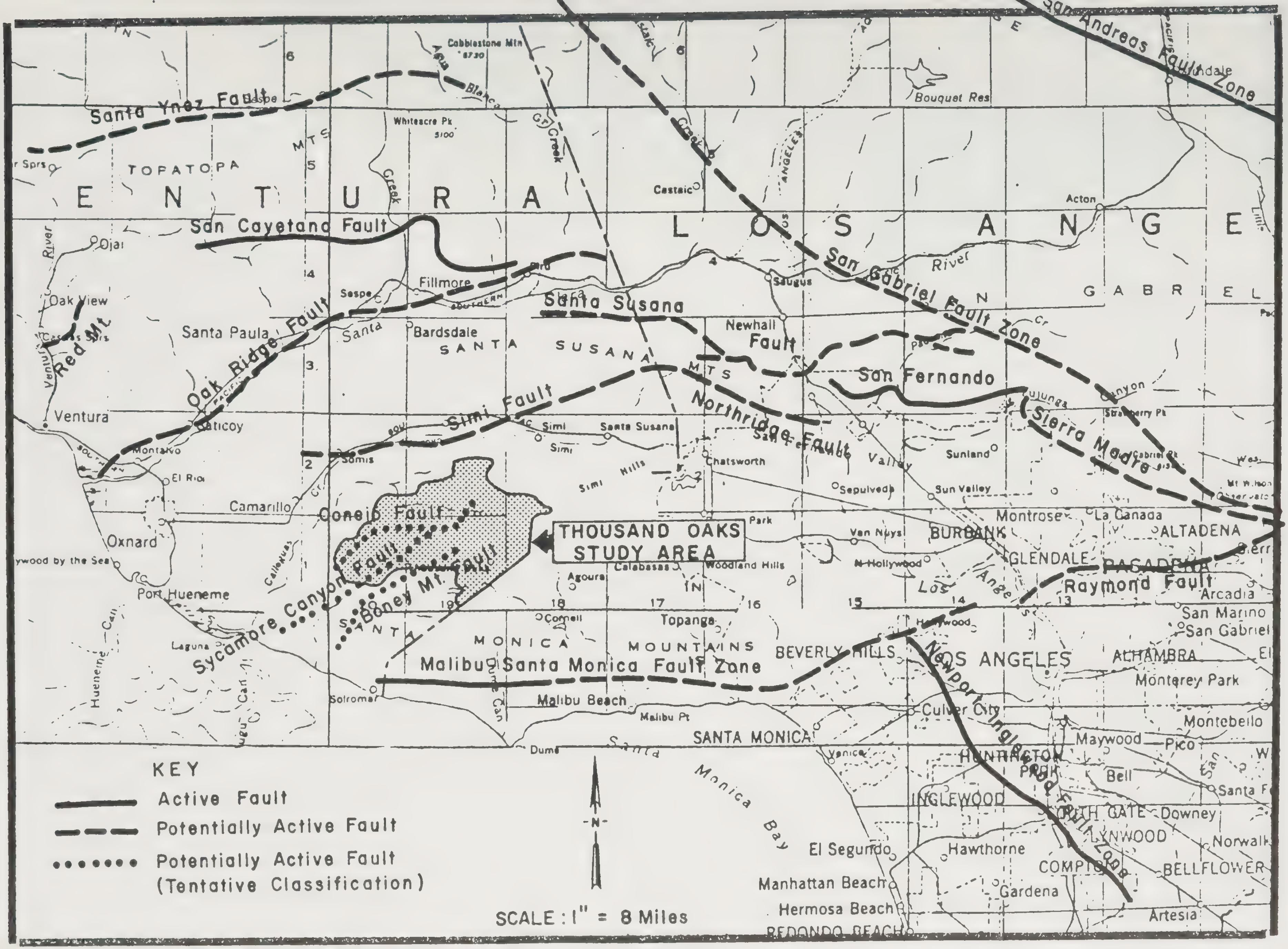
Major Faults and Geologic Events

The Thousand Oaks area lies within the Transverse Ranges which form a major structural block of the earth's crust, between the San Andreas Fault (on the northeast) and the Malibu Coast-Santa Monica Fault zone (to the south). Other regionally important faults are shown on Figure 2. Three of these, the Sycamore Canyon, Boney Mountain and the Conejo Faults, are of particular concern since they transect the south and southwest portions of the study area.

The Simi Hills, Santa Monica Mountains, Conejo Mountain, and further north the Camarillo Hills, Las Posas Hills and Oak Ridge (all of which comprise a significant component of the structural block) had their beginning in the Cretaceous period (at least 75 million years ago), when marine and non-marine sediments started to accumulate in the slowly subsiding Ventura Basin. After alternating periods of land uplift and erosion, followed by sinking and additional sedimentation, there were sporadic episodes of volcanic activity, faulting, and other earth-deforming processes (such as folding). The latest period of major mountain-building activity occurred during the middle of the Pleistocene epoch, approximately one million years ago, when most of the present-day structural features were produced.

Principal Formations

A major portion of the study area and surrounding areas, primarily to the south and west, are underlain by Miocene-age volcanic bedrock formations (the Conejo Volcanics and others) which are generally hard and quite stable. Next most prevalent are the relatively softer marine sediments of the Topanga and Modelo formations within the central and eastern sectors; these formations tend to be the most landslide-prone. The oldest formations (the Sespe, Llajas, Santa Susana and Chico Formations) make up a third bedrock group which underlies and extends



INDEX MAP OF MAJOR FAULTS

Figure 2

F. Beach Leighton & Associates

beyond the northeast corner of the study area. They have intermediate stability characteristics, compared with the other two groups.

Although deep, recent alluvial deposits are present in Santa Rosa Valley and Pleasant Valley toward the northwest, the alluvium in the study area is relatively thin (generally not exceeding 30 to 40 feet deep). These consist of Terrace Deposits, older alluvium and recent channel deposits; collectively they are laterally extensive over the study area.

GEOLOGIC SETTING WITHIN PLANNING AREA

Types of Geotechnical Hazards

For the purposes of this investigation, the geotechnical hazards are divided into two major groups, seismic and non-seismic, and include the following categories:

SEISMIC

1. Primary
   a. Ground rupture caused by fault movement.
   b. Seismic shaking.
2. Secondary
   a. Liquefaction
   b. Seismically induced settlement and landslides.
   c. Seiches
   d. Potential inundation due to dam failure.

NON-SEISMIC

1. Slope Instability
   a. Landslides
   b. Mudslides, erosion and other shallow slope failures.
   c. Slide-prone formations.
2. Soil-Related Hazards
   a. Expansive soil
   b. Settlement
   c. Subsidence
   d. Hydrocompaction
3. Other Problems
   a. Seepage, shallow groundwater.
   b. Percolation characteristics.

Mapping Techniques

Where mappable, the hazards are displayed on the Geotechnical Hazards Map (Plate I) and also referenced in the Safety Element, as required by the State guidelines. The hazards map, utilizing a modified form of conventional geologic mapping, is an interpretive map designed to facilitate land use planning by rating the various geologic hazards, which,

in turn, relate to land suitability or capability. The delineated map areas are numbered generally in their order of increasing relative risk, because of terrain conditions (slope), type and severity of geologic hazard (either existing or potential), inherent soil sensitivity (to seismic shock) or bedrock formation weakness (prone to sliding). Zones 1 and 2 have multiple risk ratings due to a greater range of conditions within that zone; refer to the Geotechnical Land Use and Hazard Classification Table (Plate III). Special hazards or zones are identified by a pattern or conventional geologic symbol.

Bedrock Formations

In order of decreasing age, the bedrock formations include the Chico, Santa Susana, Llajas, Sespe, Conejo Volcanics, Topanga and Modelo. Their distribution within the study area is shown generally on the hazards map according to the formation groupings. Brief descriptions of the bedrock composition as well as their attendant seismic, slope stability and soil-related characteristics, are included with the table (Plate III). For comprehensive descriptions, the reader is referred to the California Division of Mines and Geology Preliminary Report, PR 14, "Geology and Mineral Resources Study of Southern Ventura County, California", 1973.

RELATED SLOPE STABILITY PROBLEMS

Landslides

Indications of long-past, prehistoric slope instabilities or related slope stability problems are particularly evident within the thin-bedded, clay-rich portions of the Topanga and Modelo Formations where natural erosion processes removed lateral support by slope undercutting. Others have occurred in the older formations which are, on the average, more stable. However, they are considerably less abundant or widespread in the older formations.

Landslides shown on the Geotechnical Hazards Map are of two categories: those which are positively identified by direct field evidence; and those which are suspected to exist but are not confirmed by field data or subsurface exploration. The latter are commonly identified by aerial photointerpretation only. Many of those shown on published maps as suspected landslides have since been determined not to be landslides, after subsurface exploration. Such slides were deleted from the hazards map.

The largest landslide mapped within the study area is located above the east side of Erbes Road, south of Lang Ranch in relatively steep, undeveloped terrain; it encompasses approximately 230 acres. Rather than being a single landslide, however, it appears to be a complex series of relatively old slides.

Although landsliding can result from improper grading practices, no known significant structural damage has occurred in the City as a result of bedrock instability caused by development grading. Slides can occur, and are known to have occurred during development grading in the City, particularly where existing slide masses were encountered. The conditions were appropriately corrected, however, by removal of the slide or other stabilization measures.

Mudslides, Slumps, Erosion

These are the shallower types of slope failure, usually affecting the upper soil mantle or weathered bedrock and triggered by surface or subsurface water. Important factors related to mudslide risks are the depth and type of soil present; the direction and angle of slope; surface drainage configuration; type and condition of natural ground cover.

A comprehensive mudslide risk analysis of Southern Ventura County was made in 1971 by the California Division of Mines and Geology for HUD, after such hazards were included in the National Flood Insurance Act. Its purpose was to develop principles to determine mudslide risks and rating procedures. Criteria and principles developed in that study have conceptual application in the current seismic safety study and are generally reflected in the mapping methodology used for the hazard and land use capability maps.

Within the study area, those formations most susceptible to deep-seated landsliding (the Topanga and Modelo Formations) are also the most prone to mudslides, slumps and erosion. Historically, mudslides are most common during or shortly after a heavy rainfall or series of rainfalls (such as occurred during the winter of 1968-69). Unfortunately these can occur with great suddenness and destructive force, and are one of the leading risks to life related to slope stability hazards in southern California. One death in the Thousand Oaks area has been attributed to a mudslide.

Rockfalls

The hazard of rockfalls within the study area, although relatively minor, deserves consideration in land use planning and in evaluating the hazard to existing structures. Areas of primary concern are those located at the base of relatively steep, high slopes where rock outcroppings (usually the Conejo Volcanics) are susceptible to dislodgment of large

boulders. Such conditions are locally present along the northwest, west and south margins of the study area. The rockfall hazard is expected to be the greatest during strong earthquakes.

FAULTS WITHIN PLANNING AREA

Besides the Sycamore Canyon and Boney Mountain Faults, other faults significant to the ground rupture evaluation for the City include the Conejo Fault; the "Moorpark Freeway Fault" and the "U-2 Fault" (both names applied in this investigation to facilitate reference); and numerous unnamed subsidiary or secondary faults. Refer to the Geotechnical Hazards Map, Plate I, for fault locations.

None of the faults within the study area is known to be active; several are tentatively considered potentially active; the remainder are presumed inactive. Further, more complete discussion regarding classification of faults, ground rupture and earthquake potential is included in the Seismic Analysis section.

GENERAL SOIL CONDITIONS

Types, Distribution and Mapping

Within the soil category, for the purposes of this report, are the naturally deposited or formed near-surface earth materials, including residual soil, colluvium and slopewash. These deposits mantle all natural slopes, except those exposing bedrock at the surface. Soil depths range considerably, but generally do not exceed about 8 to 10 feet (primarily at the base of major slopes underlain by soft bedrock formations).

Soils mapping by the Soil Conservation Service of the U. S. Department of Agriculture is available for many areas, including the study area. The maps classify the surface soils according to grain-size analysis, slope, and permeability, with emphasis placed on the agricultural suitability of soils. Many other physical and chemical characteristics of the soils are also provided. Some of these are important in evaluating their engineering properties, such as shrink-swell, percolation, and erosibility. These particularly have land use planning implications, as they relate to foundation hazards or constraints, and to suitability for on-site sewage disposal. To determine the geographic disposition of each soil property, however, requires preparation of a separate interpretive map derived from the basic soil classification data. Two such maps (one showing expansive soil hazard, the other erosion potential) have been prepared by the Planning Department of Ventura County. While they are pertinent to land use planning, the data were not readily adaptable for display on the hazards map for the seismic safety element. The map units or numbered zones delineated on the hazards map, however, do take into account these soil characteristics in a general way, by the risk rating assigned.

SOIL-RELATED HAZARDS

Expansive Soil

From the difficult experience of the numerous cracked building slab complaints in the late 1950's and early 1960's came an awareness for the need to recognize and design for the hazard of expansive soil, particularly in the Thousand Oaks area. Subsequent adoption of building code revisions requiring adequate design and construction of foundations has largely mitigated the expansive soil hazard.

The swell characteristics of the surface soils (as well as of the various bedrock types) can vary widely within short distances, depending on the relative amount and type of clay present. Soils typically having the highest shrink-swell properties are those derived from clay-rich formations such as the Topanga and Modelo Formations, the old lake deposits, and certain volcanic rock types. Although the presence of expansive soil results in higher foundation costs, it is not considered to be an important land use constraint when compared with other geologic hazards. In addition, the apparent lack of correlation between the expansive soil mapping and the geologic mapping casts some doubt on the usefulness of this data.

Settlement

The sinking (or settlement) of a structure, fill prism or other imposed load is usually the result of compaction or consolidation of the underlying soil, due to its low density or compressible nature. Commonly, such soils can be found in the alluvial valley areas and where old pits or gullies have been filled in with trash and loose soil.

In the apparent absence of past settlement problems within the study area, there appears to be no need for special concern regarding its effect on land use capability, so long as the settlement potential is recognized and is appropriately minimized or corrected during construction.

Subsidence

The man-caused phenomenon of broad-scale land sinking, or subsidence, is generally related to the overpumping and depletion of water or oil from deep underground reservoirs. It is not related to the surface soil type and cannot be readily predicted without detailed subsurface data. As yet, no recognized subsidence has occurred within the study area.

Because of the generally limited groundwater resources contained in the relatively shallow alluvial basin, and the probability of very negligible future oil production, the likelihood of significant subsidence occurring in the study area is considered very minimal.

Hydrocompaction

Another form of subsidence caused by the addition, rather than the extraction of fluid, is the hazard of hydrocompaction. Because it can affect the near-surface soils very dramatically and can cause considerable structural damage to localized areas, hydrocompaction can be a serious hazard. Although it most commonly occurs in desert environments, it has been noted in some semi-arid regions of southern California.

Hydrocompaction usually occurs in relatively loose, open-textured soils above the water table. Once water is introduced, either by heavy irrigation or a rise in the water table, the soil loses its strength and consolidates under its own weight. The soil condition can also result in the phenomenon normally called settlement, where the weight of significant amounts of fill placed on top of the soil cause compaction of the subsurface soils, even though there is no change in groundwater conditions.

Although the hydrocompaction potential of the study area cannot be adequately evaluated without detailed subsurface soil data, it is not known to have occurred in the area, nor is the likelihood of its future occurrence considered great.

OTHER PROBLEMS OR DEVELOPMENT CONSTRAINTS

Groundwater Conditions

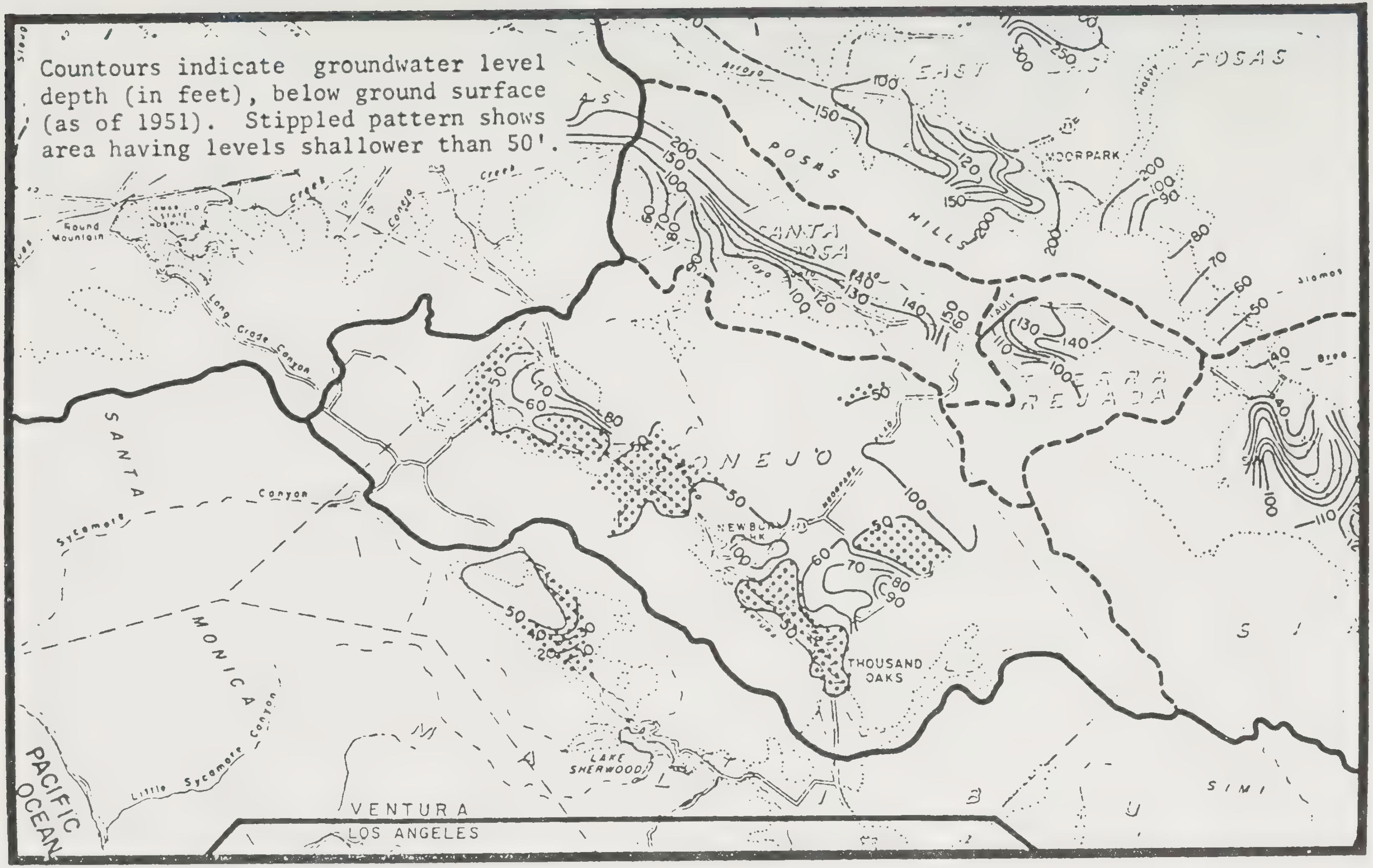
The study area falls primarily within the Conejo Basin or subunit of the larger Calleguas - Conejo Hydrologic Unit (refer to Figure 3). Most of the Westlake area is within the Malibu Hydrologic Unit, while the northerly edge of the study area is either in the Tierra Rejada or Santa Rosa Subunits. Groundwater within the Conejo Basin occurs primarily within the alluvium and permeable, weathered or fractured portions of the underlying bedrock formations. The groundwater is primarily unconfined, although multiple or localized, shallow perched water zones may be present. Depths to the water table, as of the Fall, 1951, are shown on Figure 3.

Inasmuch as nearly all of the water wells have been abandoned as a source of domestic water in more recent years, the water levels have risen somewhat from those indicated on the index map. A more current preliminary map prepared by the Planning Department of Ventura County was available for the present study and was utilized (in modified form) to determine those areas most susceptible to possible liquefaction. The hachured pattern shown on the Geotechnical Hazards Map, representing a possible liquefaction zone, corresponds to the area inside the 15-foot or shallower groundwater depth contour.

Boring logs in the broad alluvium-filled Russell Valley (the Westlake development) indicate that the groundwater is generally below a zone approximately 25 to 35 feet deep, near the base of the alluvium and above the impermeable zones of the bedrock.

Local Seepage Problems

Surfacing groundwater has appeared primarily in two subdivisions in the Thousand Oaks area, and have required remedial measures to alleviate its attendant nuisance and potential foundation problems. These areas



Modified from D.W.R.
Bulletin No. 12

Scale: 1" = 2:5 mi. ±

GROUNDWATER INDEX MAP
Thousand Oaks Area

N

FIGURE 3

are indicated on the Geotechnical Hazards Map in the vicinity of Lynn and Gainsborough Roads, and Lynn Road at Avenida de Los Arboles. Both of these seepage areas appear to be caused by natural barriers to groundwater movement, possibly from faulting or a perched water zone intercepted in a cut for development grading.

Structural distress attendant with the seepage condition in the area of Lynn Road and Avenida de Los Arboles (Tract 1499) has primarily involved cracking of swimming pools, patio and house slabs, garden walls, curbs and sidewalks. Geologic and soil investigations in the problem area have attributed the distress to one or more of the following causes: expansive soil; poor quality natural earth materials subject to consolidation, settlement or downhill creep; or instability resulting from the possible presence of ancient landslide deposits.

Prior to further construction in the problem area, additional geotechnical investigation, on a site by site basis, is recommended.

Percolation Characteristics

A possible development constraint for those areas which would rely on the use of on-site sewage disposal systems is the ability of the soil (or bedrock) to percolate, or drain away, the effluent. In general, those materials which are granular and open-textured (such as sandy or gravelly alluvium) would perform better than the older, consolidated formations composed of clay or shale (such as the Topanga or Modelo Formations). The percolation characteristics can be roughly correlated with the formation stability ratings shown on the Geotechnical Hazards Map, for the purposes of relative comparison.

MINERAL RESOURCES

General Statement

Known mineral resources within the study area are comparatively insignificant. Although numerous exploratory test wells have been drilled in the Thousand Oaks area, the only commercial oil deposit found was in the relatively shallow Conejo Field located west of the study area. Two occurrences of metallic minerals have been identified within the study area by the California Division of Mines and Geology. One is a secondary copper prospect northwest of the Lynn Ranch area above Arroyo Conejo; the other is a nickel locality in the Lindero Canyon area near the east edge of the study area. Neither deposit is of economic importance, however.

Sand, Gravel, and Crushed Rock

Only minor deposits of sand and gravel suitable for use as construction materials are probably present in the area, primarily in the recent major stream channels, such as Arroyo Conejo. Most alluvial deposits elsewhere generally contain unsatisfactory amounts of silt and clay. Additionally, the presence of mineral types which react with cement limits their possible uses.

A source of crushed rock, for use as embankment riprap or road base, has been the hard rock of the Conejo Volcanics. Areas where they were quarried (mainly in the Conejo Grade and Westlake area just southeast of the study boundary) are no longer used. Another potential source, which has been exploited in the Simi Valley area, is from the Simi conglomerate unit of the Santa Susana Formation. This deposit is limited to the Lang Ranch area, however, and it is not considered as economically important as it is in the Simi area.

SEISMIC ANALYSIS

Introduction, Analysis Approach

The seismic analysis addresses the two principal seismic hazards: ground rupture due to fault movement, and earthquake shaking. For the ground rupture analysis it is necessary to evaluate the probability of movement on a given fault within the study area, and to determine from the available data whether it is active, potentially active, or inactive. In the earthquake shaking analysis, several other secondary effects, such as liquefaction, seismically induced settlement, landslides and other types of ground failure, as well as seiches and dam safety considerations, also require appropriate evaluation.

While the ground rupture analysis is comparatively straightforward, several options are available for the seismic shaking analysis. One approach might be called the qualitative method in which the basic seismic parameters are applied in defining a general level of seismic shaking from the most probable earthquake event. The modifications in the seismic wave characteristics which occur in traveling from the bedrock level through overlying surficial alluvium and soil to the surface, can be approximated. The defined seismic ground response (either for bedrock sites or alluvial valley sites) is then translated into terms of their relative damage-producing effects (called earthquake intensity) on various types of structures.

A second type of approach is a more quantitative method which is an extension of the first method, with the intent of deriving more precise seismic parameters for the purposes of evaluating the design of structures, particularly medium or high-rise buildings. This method requires considerably more data regarding the subsurface soil and groundwater conditions than are available for this study or would be necessary to conduct a geotechnically valid analysis.

Considering the diversity of geologic conditions within the study area, the generalized nature of the data available, and the City's stage of development, therefore, the first method was the approach selected for the present study. It is believed that the resulting analysis conforms with the intent of the seismic safety element, and best meets the needs of the City within the work scope authorized.

Fault Classification

Although there are many definitions of active, potentially active and inactive fault, there now appears to be general acceptance of the classification criteria adopted by the State Mining and Geology Board relative to State legislation delineating special studies zones along active faults (Alquist-Priolo Bill). This classification is used in this report. Thus, an active fault is one which has moved within about the last 11,000 years (Holocene time), or which has exhibited earthquake activity. A fault which has moved during the last 2 to 3 million years (Pleistocene time) but not proven by direct evidence to have moved within the last 11,000 years is considered to be potentially active. Any fault older than Pleistocene (one which does not displace rocks 2 to 3 million years old) is considered inactive. Refer to Figure 4 for geologic time scale.

Since age-dating of latest movement is available only in rare instances, many faults which are in fact active are necessarily classified as potentially active because of the lack of data.

Sycamore Canyon Fault: This is a major fault extending at least 15 miles southwest from Thousand Oaks to Point Mugu, where it apparently continues offshore. Refer to Index Map of Major Faults, Figure 2. Its location or existence northeast of the central part of Thousand Oaks is uncertain, based on present knowledge. Although no evidence of Pleistocene or more recent movement has been found on this fault, it tentatively should be considered potentially active, at least for planning purposes.

GEOLOGIC TIME SCALE SHOWING FAULT CLASSIFICATIONS

RELATIVE GEOLOGIC TIME			ATOMIC TIME (in millions of years)
Era	Period	Epoch	
Cenozoic	Quaternary	Holocene	.011
		Pleistocene	2-3
	Tertiary	Pliocene	12
		Miocene	26
		Oligocene	37-38
		Eocene	53-54
		Paleocene	65
Mesozoic	Cretaceous	Late Early	136
	Jurassic	Late Middle Early	190-195
	Triassic	Late Middle Early	225
Paleozoic	Permian	Late Early	280
	Carbon-iferous Systems: Pennsyl-vanian	Late Middle Early	
	Carbon-iferous Systems: Mississip-pian	Late Early	345
	Devonian	Late Middle Early	395
	Silurian	Late Middle Early	430-440
	Ordovician	Late Middle Early	500
	Cambrian	Late Middle Early	570
Precambrian			3,600+

ACTIVE FAULTS*

POTENTIALLY ACTIVE FAULTS

INACTIVE FAULTS

*As defined by policies & criteria of State Mining & Geology Board

FIGURE 4

Boney Mountain Fault: This is a southerly branch of a zone including the Sycamore Canyon Fault, and like that fault, extends to the coast. Similarly, its northeast extent is the subject of some conjecture. Some believe it may connect with the "Moorpark Freeway" Fault. The Boney Mountain Fault tentatively should be considered potentially active.

Conejo Fault: This probably is a northwesterly branch of the aforementioned zone. Although its southwest extent is in doubt, it probably does not reach the coast. The fault apparently joins the Sycamore Canyon Fault in the central part of Thousand Oaks, and likewise, should be considered potentially active.

Moorpark Freeway, U-2, and Other Faults: Two smaller faults, which may be secondary branches of the previously mentioned faults, include the Moorpark Freeway and U-2 Faults. Refer to the Geotechnical Hazards Map, Plate I, for their location. For the purposes of this report, both of these are considered inactive.

The U-2 Fault, so named in this report because it was first recognized on high altitude aerial photographs flown by a U-2 aircraft, was recently verified in the field by the California Division of Mines and Geology (personal communication with F. H. Weber, Jr.). No evidence of Pleistocene or younger movement on the fault has been found, however. It appears to be a secondary branch of the Sycamore Canyon Fault.

All other mapped faults within the study area are relatively minor and considered inactive.

Fault Rupture Hazard

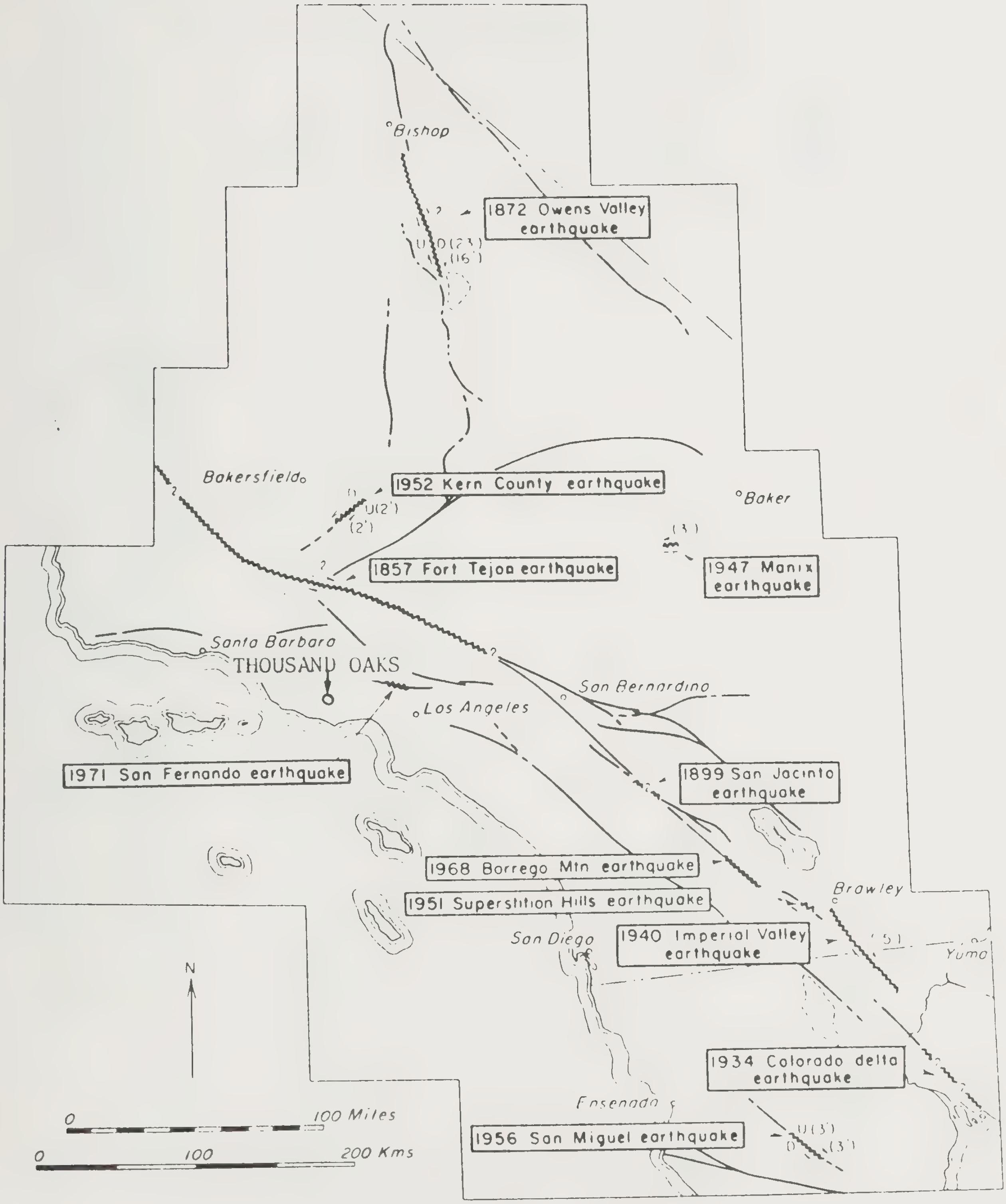
The hazard of damage caused by ground displacement from fault movement, although it is generally associated only with large earthquakes on major faults, requires appropriate evaluation in regard to faults within

the planning area. Figure 5 shows historic fault breaks associated with larger regional earthquakes. Since none of the faults is classified as active, the provisions of the Alquist-Priolo Geologic Hazards Zone Act (which establishes special studies zones under State jurisdiction for active faults) do not apply to the study area. However, the Act also will include those faults considered potentially active and, therefore, may have future bearing on investigation standards or building setbacks from faults, primarily the Conejo, Sycamore Canyon and Boney Mountain Faults. For the purposes of land use planning only, these faults are shown as a zone at least one-eighth to one-quarter mile wide on the Geotechnical Hazards and Land Use Capability Maps.

The ground rupture risk, although relatively low, compared to other major faults in the region, is somewhat greater for the named potentially active faults than for the smaller inactive faults. Even though earthquakes may not originate on the faults, there is a remote possibility of "sympathetic" movement resulting from a large earthquake on another nearby fault. In no case is it advisable to build a structure across a significant fault.

Regional Seismicity and Earthquake History

It is acknowledged that California, with its numerous active faults, is one of the most earthquake-prone regions of the United States. In the southern California area alone, several hundred earthquakes (ranging from about 1 to 6 Richter magnitude) have been recorded since measuring instruments were installed. A list of prominent earthquakes in California since 1769 is presented in Table 1. Location of epicenters for earthquakes of magnitude 6.0 or greater are shown on Figure 6; an index map including those earthquakes equal to or greater than 4.0 are shown on Figure 7.



Historic fault breaks and associated earthquakes in the southern California region, modified from Hileman, et al (1973)

FIGURE 5

Table 1

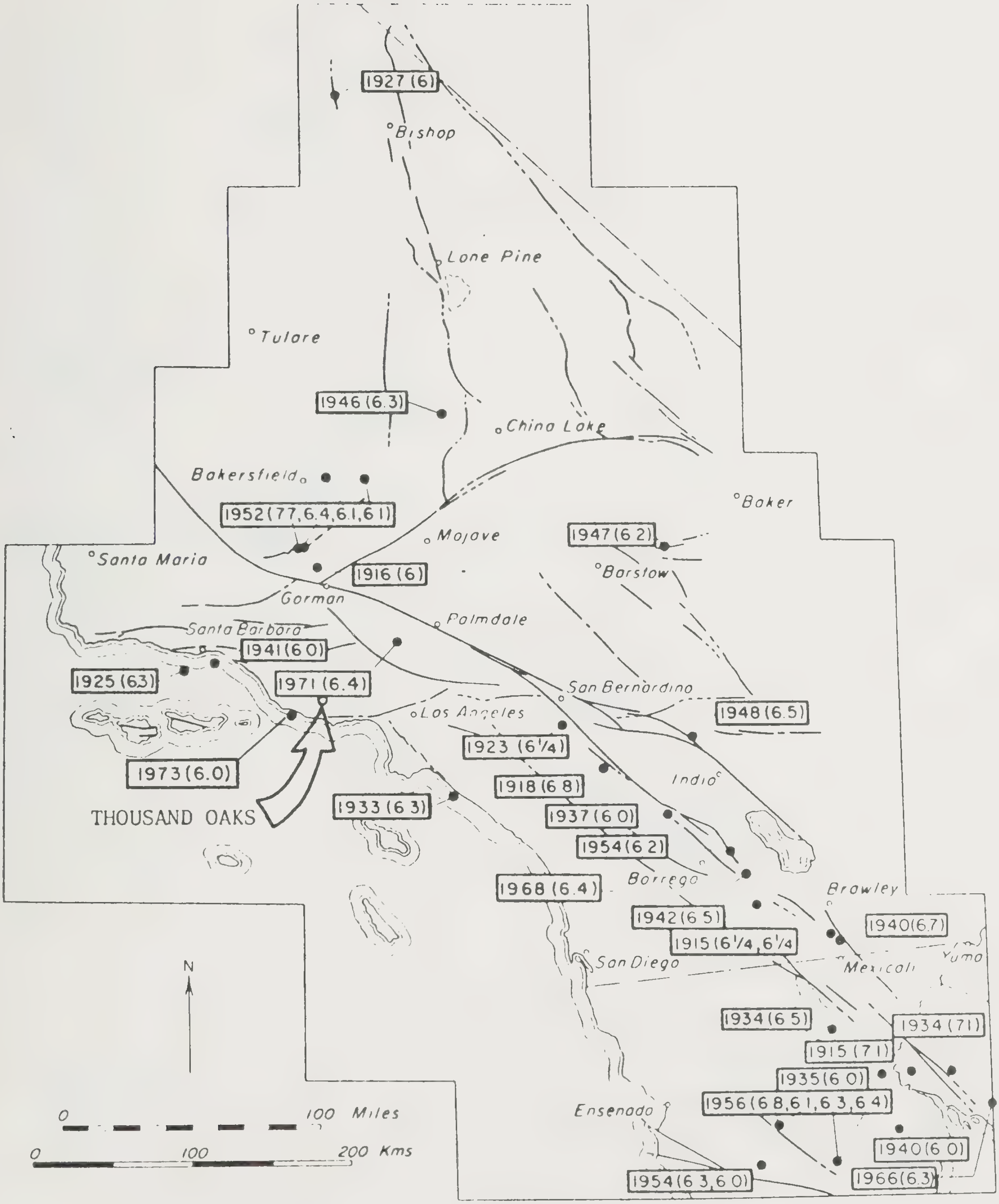
Prominent earthquakes in California, 1769 through September 1971

(Intensity VIII and above)

Date		Region	Richter Magnitude	Modified Mercalli Intensity
28	Jul 1769	Los Angeles region	*	
8	Dec 1812	Southern California		VIII-IX
21	Dec	Off coast of southern California		X
10	Jun 1836	San Francisco Bay		IX-X
	Jun 1838	San Francisco region		X
10 or 11	Jul 1855	Los Angeles County		VIII
9	Jan 1857	Near Fort Tejon	Possibly 8	X-XI
26	Nov 1858	San Jose		VIII
12	Nov 1860	Humboldt Bay		VIII
3	Jul 1861	Near Livermore		VIII
1	Oct 1865	Fort Humboldt-Eureka area		VIII-IX
8	Oct	Santa Cruz Mountains		VIII-IX
21	Oct 1868	Hayward		IX-X
26	Mar 1872	Near Lone Pine	Possibly 8	X-XI
19	Apr 1892	Vacaville		IX
21	Apr	Winters		IX
4	Apr 1893	Northwest of Los Angeles		VIII-IX
20	Jun 1897	Near Hollister		VIII
14	Apr 1898	Mendocino area		VIII-IX
22	Jul 1899	San Bernardino County		VIII
25	Dec	San Jacinto-Hemet area		IX
27 & 31	Jul 1902	Santa Barbara County		VIII
18	Apr 1906	San Francisco region	8.3	XI
18	Apr	Brawley, Imperial Valley	6 to 6.9	VIII
28	Oct 1909	Humboldt County	6+	VIII
11	Jan 1915	Los Alamos		VIII
22	Jun	El Centro-Calexico-Mexicali area	6.25	VIII
21	Apr 1918	San Jacinto-Hemet area	6.8	IX
21	Jun 1920	Inglewood		VIII
10	Mar 1922	Cholame Valley	6.5	IX
29	Jun 1925	Santa Barbara area	6.3	VIII-IX
22	Oct 1926	Monterey Bay	6 to 6.9	VIII
20	Aug 1927	Humboldt Bay		VIII
4	Nov	West of Point Arguello	7.5	IX-X
25	Feb 1930	Westmorland	5.0	VIII
1	Mar	Brawley	4.5	VIII
6	Jun 1932	Humboldt County	6.4	VIII
10	Mar 1933	Near Long Beach	6.3	IX
7	Jun 1934	Parkfield	6.0	VIII
18	May 1940	Imperial Valley	7.1	X
30	Jun 1941	Santa Barbara-Carpinteria area	5.9	VIII
15	Mar 1946	North of Walker Pass	6.25	VIII
29	Jul 1950	Imperial Valley	5.5	VIII
21	Jul 1952	Kern County	7.7	XI
22	Aug	Bakersfield	5.8	VIII
25	Apr 1954	East of Watsonville	5.25	VIII
21	Dec	Eureka	6.6	VII
8	Apr 1968	Northeast San Diego County	6.5	VII
1	Oct 1969	Santa Rosa	5.7	VII-VIII
9	Feb 1971	San Fernando	6.6	VIII-XI

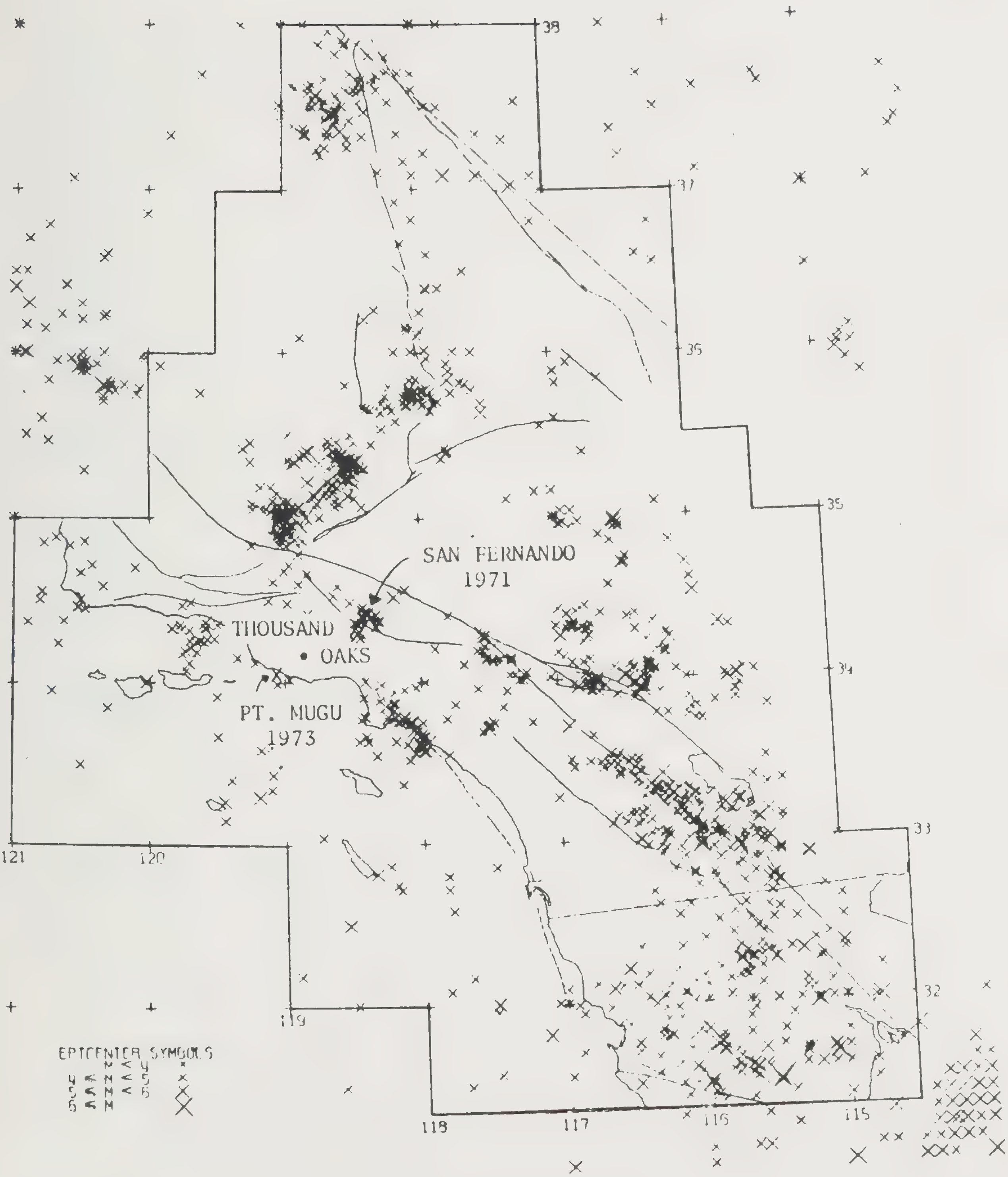
* The Richter magnitude scale was not devised until 1931. If values appear in this column for earthquakes which occurred prior to that date, the magnitudes were determined as follows: 1) if given to the nearest tenth, the records of older instruments were correlated with records of instruments now in use; 2) otherwise, historical records of intensity were used to estimate magnitude.

Source: California Geology



Earthquakes of magnitude 6.0 and greater in the southern California region, 1912-1972, modified from Hileman, et al (1973)

FIGURE 6



1932 THROUGH 1972. EVENTS EQUAL OR GREATER THAN MAGNITUDE -4
Modified from Hileman, et al, (1973)

FIGURE 7

The earthquake history of southern Ventura County has been characterized by relatively small shocks of 4.7 magnitude or less, with several significant larger exceptions occurring in the adjoining offshore areas (see Figure 7). These larger, more distant earthquakes, were undoubtedly felt with greater intensity in Thousand Oaks than were the smaller, nearby quakes. Significant damage was reported in the Santa Barbara and Ventura areas from the 1812, 1857 and 1925 earthquakes. More recently and closer to the Thousand Oaks area were reports of significant local damage in the Simi Valley area caused by the 1971 San Fernando quake, and the strong intensities and minor damage experienced in the Thousand Oaks area as a result of the 1973 Point Mugu quake. The latter earthquake caused significant damage locally in the Oxnard-Ventura area; it is believed to have occurred along the Malibu Coast-Santa Monica Fault system, rather than along the Sycamore Canyon or Boney Mountain Faults.

Earthquake Shaking Evaluation

Ground shaking generated by earthquakes causes, by far, more damage over a wider area than does surface rupturing by faults. It is estimated that 99% of the dollar loss from the 1971 San Fernando Earthquake was due to shaking damage, and only 1% attributed to surface rupturing. Although earthquake prediction may be a reality in the not too distant future, the seismologist must rely on the means at hand to estimate where and how large the next quake will be, how often it will occur and determine what effect it will have at a particular site. Even with the installation of greater numbers of earthquake recording instruments providing more sophisticated data with which to analyze each shock, determining the numerous seismic parameters for that site is by no means an exact science. A review of the earthquake history of the region, even though the early records are sketchy and incomplete, is necessary for the seismic evaluation of the site.

Important factors which determine the shaking intensity at a given location are:

1. Distance from the earthquake.
2. Size or magnitude of the earthquake.
3. Local soil, geologic and groundwater conditions.

Other parameters which are measured or calculated include ground acceleration, predominant period, duration of strong motion, velocity and displacement.

Earthquake Intensity: This is a qualitative measure of an earthquake's size determined by the relative damage caused, or observed effects noted, measured usually on the Modified Mercalli Scale; see Table 2. Data from past earthquakes have shown that the intensity of ground shaking can be several times greater on sites underlain by thick, soft alluvial deposits than on bedrock. This results from the amplifying effects on the seismic wave as it passes from the bedrock, up through the slower velocity alluvium and soil to the surface. The extent of shaking damage is also dependent partly on the structural integrity of building (i. e. the type and condition of the building).

Magnitude: Earthquake magnitude is a measure of the energy released, based on an open-ended scale, such as the widely used Richter Scale. Each increase of magnitude number on this scale represents a 10 times greater seismic wave amplitude measured on the seismogram recorded by an instrument, because of the logarithmic character of the scale. Earthquake potential of a given fault depends on the total length of the fault, the portion likely to rupture at one time, and the amount of stress build up which has occurred since the previous earthquake. Very long faults, therefore, such as the San Andreas Fault, are capable of producing much larger earthquakes than shorter ones, like the Conejo Fault.

Table 2 Modified Mercalli scale of earthquake intensities.

THE MERCALLI INTENSITY SCALE
(As modified by Charles F. Richter in 1956 and rearranged)

If most of these effects are observed	*then the intensity is:*
Earthquake shaking not felt. But people may observe marginal effects of large distance earthquakes without identifying these effects as earthquake caused. Among them: trees, structures, liquids, bodies of water sway slowly, or doors swing slowly.	*I*
Effect on people. Shaking felt by those at rest, especially if they are indoors, and by those on upper floors.	*II*
Effect on people. Felt by most people indoors. Some can estimate duration of shaking. But many may not recognize shaking of building as caused by an earthquake; the shaking is like that caused by the passing of light trucks.	*III*
Other effects. Hanging objects swing. *Structural effects:* Windows or doors rattle. Wooden walls and frames creak.	*IV*
Effect on people. Felt by everyone indoors. Many estimate duration of shaking. But they still may not recognize it as caused by an earthquake. The shaking is like that caused by the passing of heavy trucks, though sometimes, instead, people may feel the sensation of a jolt, as if a heavy ball had struck the walls. *Other effects:* Hanging objects swing. Standing autos rock. Crockery clashes, dishes rattle or glasses clink. *Structural effects:* Doors close, open or swing. Windows rattle.	*V*
Effect on people: Felt by everyone indoors and by most people outdoors. Many now estimate not only the duration of shaking but also its direction and have no doubt as to its cause. Sleepers wakened. *Other effects:* Hanging objects swing. Shutters or pictures move. Pendulum clocks stop, start or change rate. Standing autos rock. Crockery clashes, dishes rattle or glasses clink. Liquids disturbed, some spilled. Small unstable objects displaced or upset. *Structural effects.* Weak plaster and Masonry D* crack. Windows break. Doors close, open or swing.	*VI*
Effect on people. Felt by everyone. Many are frightened and run outdoors. People walk unsteadily. *Other effects.* Small church or school bells ring. Pictures thrown off walls, knicknacks and books off shelves. Dishes or glasses broken. Furniture moved or overturned. Trees, bushes shaken visibly, or heard to rustle. *Structural effects.* Masonry D* damaged; some cracks in Masonry C*. Weak chimneys break at roof line. Plaster, loose bricks, stones, tiles, cornices, unbraced parapets and architectural ornaments fall. Concrete irrigation ditches damaged.	*VII*
Effect on people. Difficult to stand. Shaking noticed by auto drivers. *Other effects.* Waves on ponds, water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Furniture broken. Hanging objects quiver. *Structural effects.* Masonry D* heavily damaged. Masonry C* damaged, partially collapses in some cases; some damage to Masonry B*; none to Masonry A*. Stucco and some masonry walls fall. Chimneys, factory stacks, monuments, towers, elevated tanks twist or fall. Frame houses moved on foundations if not bolted down, loose panel walls thrown out. Decayed piling broken off.	*VIII*
Effect on people. General fright. People thrown to ground. *Other effects.* Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes. Steering of autos affected. Branches broken from trees. *Structural effects.* Masonry D* destroyed; Masonry C* heavily damaged, sometimes with complete collapse. Masonry B* is seriously damaged. General damage to foundations. Frame structures, if not bolted, shifted off foundations. Frames racked. Reservoirs seriously damaged. Underground pipes broken.	*IX*
Effect on people. General Panic. *Other effects.* Conspicuous cracks in ground. In areas of soft ground, sand is ejected through holes and piles up into a small crater, and, in muddy areas, water fountains are formed. *Structural effects.* Most masonry and frame structures destroyed along with their foundations. Some well built wooden structures and bridges destroyed. Serious damage to dams, dikes and embankments. Railroads bent slightly.	*X*
Effect on people. General panic. *Other effects.* Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. *Structural effects.* General destruction of buildings. Underground pipelines completely out of service. Railroads bent greatly.	*XI*
Effect on people. General panic. *Other effects.* Same as for Intensity X. *Structural effects.* Damage nearly total, the ultimate catastrophe. *Other effects.* Large rock masses displaced. Lines of sight and level distorted. Objects thrown into air.	*XII*

* Masonry A: Good workmanship and mortar, reinforced, designed to resist lateral forces.
Masonry B: Good workmanship and mortar, reinforced.
Masonry C: Good workmanship and mortar, unreinforced.
Masonry D: Poor workmanship and mortar and weak materials, like adobe.

Source: CDMG Bulletin 198

Statistically, since numerous smaller earthquakes are more likely to occur on a given fault than a single large quake, it is important to determine the recurrence interval for a given magnitude earthquake for a particular fault so that a judgment can be made regarding the size of earthquake to be used for design of structures. Important structures or facilities (such as a hospital) require greater safety than do less important ones (such as a warehouse) and, therefore, are designed for the less likely, larger earthquake.

Credible and Probable Earthquakes: As used in this study, the maximum credible earthquake is the largest event likely to occur on an active fault, and having a recurrence interval of greater than 200 years. Although the probability of such an earthquake is considered to be very low, it is within the realm of possibility. This would be the controlling seismic event for the design of very critical or important structures such as a nuclear reactor or hospital. Refer to Table 3 for estimated maximum earthquake magnitudes for the region.

For potentially active faults, the recurrence interval probably exceeds 300 to 500 years, with maximum credible magnitude estimated from empirical data based on 1/2 fault length rupture. These are not usually considered for design purposes, unless ultra-conservative designs are required.

The maximum probable earthquake is the largest quake most likely to occur on an active fault during the life of a structure, approximately 50 to 100 years. For a potentially active fault, the recurrence interval is probably 300 years or more. The maximum probable earthquake on an active fault is generally used for the design of most "ordinary" types of structures.

TABLE 3
SUMMARY OF ACTIVE & POTENTIALLY ACTIVE FAULTS
AND THEIR EARTHQUAKE PARAMETERS

CLASSIFI-CATION	FAULT	DISTANCE TO EPICENTER (miles)	MAXIMUM HISTORICAL EARTHQUAKE MAGNITUDE (RICHTER)	ESTIMATED MAXIMUM EARTHQUAKES			
				MAX. CREDIBLE[1]		MAX. PROBABLE[2]	
				Magnitude (Richter)	Est. Recurr. Interval (Yrs)	Magnitude (Richter)	Est. Recurr. Interval (Yrs)
ACTIVE Controlling Seismic Events	San Andreas	36-44	8.0 ± 0.5 (1857) 6.5 (1948)	8.25	>200	8.0	50-200[3]
	San Fernando-Sierra Madre	18-42	6.4 (1971)	6.7	>200	6.3	50-200
	Newport-Inglewood	25-35	6.3 (1933)	7.3	>300	6.7	50-150
	Malibu Coast-Santa Monica	6-14	6.0	6.8	>500(?)	6.3	>200(?)
POTENTIALLY ACTIVE Other Regional & Local Seismic Events	Santa Ynez	23-31	--	7.5	>500(?)	7.0	>300(?)
	San Gabriel	20-28	--	7.5		7.0	
	Red Mt.-San Cayetano (4)	10-18	--	6.9		6.4	
	Oak Ridge	9-17	--	6.8		6.2	
	Simi-North-ridge	1-9	--	6.7		6.2	
	Santa Susana	11-18	--	6.5		5.9	
	Sycamore Canyon (5)	Within	--	6.4		5.7	
	Boney Mtn. (5)	Study	--	6.1		5.5	
	Conejo (5)	Area	--	5.8		5.2	

(1) Based on 1/2 fault length; magnitudes after Bonilla.
(2) Based on 1/5 fault length.
(3) Wallace, R.E.
(4) Probably active by State criteria.
(5) Tentative classification.

Earthquake Design Parameters For Study Area: Table 4 lists the important seismic shaking components which should be considered in the design of new structures or evaluation of the performance of existing structures within the study area. Of the potential earthquake generators, the San Andreas Fault and the Malibu Coast Fault appear to be the most important for design analysis, in terms of bedrock acceleration values. For sites on thick soil or deep alluvium, however, the seismic motion components are modified somewhat (depending on the soil consistency, depth, and groundwater conditions) and the ground acceleration, although slightly less than for the bedrock site, is less important than the increased earthquake intensity which results from the amplification effects of the alluvium. Therefore, it is necessary to evaluate all of the parameters of the controlling seismic events, taking into consideration the fundamental period of the structure being studied.

The maximum bedrock acceleration values are applicable to design or analysis of one and two-story residential structures, and most commercial and industrial construction on bedrock sites or sites underlain by relatively thin, firm alluvium (most of Thousand Oaks area). For medium-or high-rise structures, including all critical use or high-cost facilities, a seismic response spectrum should be developed for the specific site under consideration. The general seismic parameters developed in this report can be used as a basis for the refinement of more specific design parameters, taking into account the detailed data pertinent to that site.

Secondary Seismic Hazards

Liquefaction and Related Ground Failure Phenomena: Liquefaction, one of the more important secondary seismic hazards, can be described as a "quicksand" condition in which there is a total loss of foundation support caused by a shock (usually an earthquake of significant magnitude). This condition results from a sudden decrease of shearing

TABLE 4

MAXIMUM PROBABLE EARTHQUAKES

(To be Considered for Aseismic Design of Most Structures)

FOR

CITY OF THOUSAND OAKS

CAUSATIVE FAULT	DISTANCE FROM CAUSATIVE FAULT (Miles)	RICHTER MAGNITUDE	MAXIMUM BEDROCK ACCELERATION[1] (g)	PREDOMINANT PERIODS[2] (Seconds)	BRACKETED DURATION[3] (Seconds)
San Andreas Fault Zone	36 - 44	8.0	.16 - .20 (VII - VIII)[4]	0.4 - 0.5	29
San Fernando-Sierra Madre Fault Zone	18 - 42	6.3	.05 - .17 (VI - VII)	0.25 - 0.30	8 - 13
Newport-Inglewood Fault Zone	25 - 35	6.7	.08 - . 15 (VII)	0.30 - 0.32	17 - 19
Malibu Coast-Santa Monica	6 - 14	6.3	.18 - .35 (VIII)	0.25	14 - 16

(1) Base Rock Motion (Schnabel & Seed, 1972)

(2) Seed, Idriss & Kiefer, 1969

(3) Leeds, 1973

(4) Approximate equivalent Modified Mercalli Intensity range within study area.

resistance in a cohesionless soil (such as sand) accompanied by a temporary increase in pore-water pressure. Important factors in determining liquefaction potential are the intensity and duration of shaking, and the presence of relatively low-density fine sand and silt, in an area of shallow groundwater.

Another type of liquefaction, which occurs at some depth from the surface, can, instead of causing widespread loss of foundation support, result in ground lurching, fissuring or cracking. These effects are ascribed to flow landsliding or lateral spreading landslides which can occur at very low angles.

Within the study area, only those portions having the highest relative liquefaction potential were identified. This was based primarily upon alluvial areas having groundwater depths less than 15 feet. Because of the preliminary nature of the liquefaction analysis for this study, the parameter of soil type could not be thoroughly evaluated. Therefore, it should not be assumed that all areas within the identified zone will have equal liquefaction potential, due to differences in subsoil conditions. The zones are not an absolute measure of liquefaction, but only a relative, broad-scale rating for comparison with other areas within the study area. A more definitive liquefaction evaluation of a specific site would require an in-depth analysis of the controlling parameters. Additional study may reveal other areas not delineated on the hazards map which have relatively high liquefaction potential also, particularly if the groundwater levels rise.

For critical-use structures, such as hospitals, the Veterans Administration has established certain criteria for determining whether liquefaction investigations are to be required. Sites requiring the study are based on the following criteria:

1. Sites with anticipated earthquake intensities of MM VII or greater.
2. Subsoils with saturated fine sand layers with 50% or more of grain size less than 2 millimeters, at a depth of 45 feet or less.

3. Subsoils having relative densities of 40% or less, considering a MM VII or greater earthquake intensity, or a relative density of 75% or less, considering a MM IX or greater earthquake intensity.

Similar guidelines should be considered for adoption by the City for critical use structures.

Seismically Induced Settlement: In the absence of a shallow water table, but with soil conditions otherwise ideal for liquefaction, settlement can occur in some degree, depending upon the intensity of shaking and the looseness of the soil. Such a compacting process would damage structures primarily where there is significant differential settlement within a short distance in alluvial valley areas, or where a site was partially on a bedrock formation and partially on a fill subject to internal compaction or settlement of unsuitable subsoils. The delineation of areas subject to such a hazard could not be determined within the present investigation scope.

Seismically Induced Landsliding: Very marginally stable slopes (including existing landslides) may be subject to landsliding caused by seismic shaking. In many cases, such as in the 1971 San Fernando earthquake, they are limited to relatively shallow failures on the steeper slopes, particularly where the soil is relatively thick and loose. They may take the form of debris falls or rolling boulders, where the slopes are particularly steep and expose hard rock outcroppings. Formations which may be particularly susceptible to such hazards are indicated on the hazard classification table (Plate III).

Seiches: A seiche, or an earthquake-induced wave in a confined body of water, could affect areas adjacent to lakes or reservoirs. Aside from the potential shoreline damage or damage to improvements such as dock facilities and boats, the most serious consequence of

a seiche would be the overtopping and possible failure of a dam. The principal water bodies within the study area which could be affected by seiches are the lake at Westlake Village and Lake Eleanor (only if refilled); Lake Sherwood and Westlake Reservoir are outside of the study area but have an influence on the study area since they are located upstream.

Our preliminary analysis of the potential height of seiches in any of the lakes indicates that they would not exceed approximately one foot. Locally, however, they could range up to slightly greater than three feet adjacent to areas of deeper water, or due to irregularities in lake configuration.

Although dam safety was not specifically evaluated in this study, the potential seiche hazard should be considered in any detailed assessment of dam safety (under State jurisdiction). Likewise, the design of enclosed reservoirs or tanks should allow for the increased forces against the sides caused by the wave action or "sloshing" effect.

Potential Inundation Due to Dam Failure: The State Office of Emergency Services, since the 1971 San Fernando earthquake, has been charged with the responsibility of delineating all areas subject to inundation due to dam failure (for all those dams under state jurisdiction). The mapping thus far, however, does not indicate relative hazard potential or involve specific analysis of the seismic stability of each dam. The State Division of Dam Safety of the Department of Water Resources is currently identifying those dams most susceptible to seismically caused failure, mainly according to their age, type of construction and present physical condition. These, and others, will be specifically investigated for seismic stability on a priority basis.

Those dams which are not believed to be seismically vulnerable are <u>certified</u> for continued use by the State. Some are certified with a limitation on the maximum water level, if there is some doubt as to the dam's stability. According to State records, both the dams at Lake Sherwood and Westlake Reservoir are certified to operate at full capacity.

The potential inundation areas shown in the area of Westlake Village is only theoretical and is not expected to have a significant impact on land-use planning.

APPENDIX A

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APPENDIX B

AERIAL PHOTOS REFERENCED

Year of Photography	Flight Number	Photo Number	Scale	Agency
1928	C-300	H47-48, 60-62, 75-77, J1-2	1500'	Fairchild
1936	C-3981	14-19, 28, 32, 33, 38-42	2000'	Fairchild
1938	C-5202	28-37	1320'	Fairchild
1940	6673	6-10, 17-19	2000'	Fairchild
1945	9800	68-71	600'	Fairchild
1959	AX1-11W	55-59, 86-89	1000'	USDA
1968	AH-040	1-10, 11-20, 50-61, 63-73, 74-85	500'	American-Hawaiian
1973	Photomaps of City of Thousand Oaks; Various map sheets		100'	Pac. Western Aerial Surveys

APPENDIX C

GLOSSARY OF TERMS

ACCELERATION
: Rate of change in velocity; felt as a force by objects. Measured in units of gravity (g).

ALLUVIUM
: A general term for unconsolidated sediment (such as sand and gravel) deposited during relatively recent geologic time by a stream or other body of running water.

ASEISMIC
: Earthquake resistant or non-seismic.

BEDDING
: The arrangement of sedimentary rocks in layers or strata (separated by surfaces called bedding planes).

BEDROCK
: Firm or coherent rock material that underlies the soil and surficial deposits such as alluvium. It is divided geologically into three principal types: Igneous (e.g.granite), sedimentary (sandstone) and metamorphic (gneiss).

COLLUVIUM
: A thick deposit of soil-like material on or at the base of slopes as a result of gravitational forces, deep weathering, and sheet erosion.

CONGLOMERATE
: A sedimentary rock composed of rounded, pebble or cobble to boulder-size fragments, usually in a finer matrix of sand.

CRITICAL-USE STRUCTURE
: Synonomous with vital or essential facilities, as used in this study. Refers to important structures which must remain

functional and safe for occupancy after a severe earthquake. Types of structures included in this category varies but generally include such facilities as hospitals, fire stations, police and other emergency operational centers, and major power or communication complexes.

<u>EPICENTER</u>

The point on the earth's surface directly above the focus or hypocenter of an earthquake (originating point within the earth).

<u>EXPANSIVE SOIL</u>

A soil which undergoes a significant and reversible change in volume resulting from a change in moisture content.

<u>FAULT</u>

A fracture or plane of breakage in soil or rock, along which there has been relative movement of the two sides due to earth-deforming forces. Faults are classified according to the type of relative movement and recency of latest movement. (See page 36 of this report.)

<u>FAULT TRACE</u>

The line of intersection of a fault with the earth's surface.

<u>FAULT ZONE</u>

Typical of major faults, where numerous sub-parallel and intersecting fault traces characterize a wide band of faulting.

<u>FORMATION</u>

A rock unit which can be recognized, named, and mapped, e.g., the Topanga Formation.

<u>GEOTECHNICAL</u>

Pertaining to geologic-soils engineering studies, features, conditions or events.

<u>GROUND RUPTURE</u>

See SURFACE RUPTURE.

<u>GROUNDWATER</u>

That part of the subsurface water which is in the zone of saturation.

<u>HYPOCENTER</u>

In an earthquake, the point of initial rock rupture or slippage within the earth. Same as focus.

<u>INTENSITY</u>

A qualitative or subjective measure of the destructiveness of an earthquake based on observed effects or sensations experienced by people; a number scale, e.g., <u>Mercalli</u>.

<u>LIQUEFACTION</u>

The sudden, large decrease of shearing resistance of a cohesionless soil caused by collapse of the soil structure, produced by seismic shaking or small shear strains, associated with sudden but temporary increase of water pressure in the soil voids. For additional discussion and related phenomena, see page 49 of this report.

<u>LURCHING</u> (or Ground Lurching)

Surface cracking or similar ground failure resulting from strong seismic shaking; related to liquefaction or subsurface flowage.

MAGNITUDE

A quantitative instrumental measure of the total energy release of a quake; a logarithmic number scale, e.g., Richter.

PERIOD

The time interval for a complete cyclic motion, as in a graph of an earthquake event; reciprocal of frequency.

Fundamental Period: The longest period for which a structure or soil column shows a response peak - commonly the period of maximum response; same as site period.

Predominant Period: That period characteristic of the strongest earthquake motion. Predominant period increases with distance from the epicenter.

RECURRENCE INTERVAL

The average length of time between earthquake events of a specified magnitude.

RESPONSE SPECTRUM

A plot of the response of a number of single-degree-of-freedom systems to a real or synthetic ground motion time-history; a quantified description of the vibratory effect of the ground acceleration on buildings.

Ground Motion Spectrum: A tripartite logorithmic plot of maximum expected seismic motion at a site, representing ground displacement, velocity and acceleration. The curve from which the response spectra are derived.

SANDSTONE

A sedimentary rock of cemented sand-size particles.

SATURATED

A rock or soil is saturated with respect to water if all its interstices are filled with water.

SEDIMENTARY ROCK

The class of rocks made up of transported and deposited rock and mineral particles (sediment) and of chemical substances derived from weathering.

SEICHE

Earthquake-induced waves in lakes, ponds, bays, or other enclosed bodies of water; also caused by landsliding.

SEISMIC

Pertaining to or caused by an earthquake.

Seismicity: Earth movement phenomena as related to earthquakes; also a measure of the area's susceptibility to earthquakes.

SETTLEMENT

The downward movement of a soil or of the structure which it supports, resulting from a reduction in the voids in the underlying strata.

SHALE

A thinly layered or stratified sedimentary rock of clay-size particles.

SILTSTONE

A sedimentary rock of cemented particles intermediate in size between sand and clay (silt).

STRATIFICATION

A structure of sedimentary rocks produced by deposition in layers (beds).

SUBSIDENCE

The relatively slow, gradual sinking of a large area in a vertical direction with little or no horizontal movement. Commonly related to the withdrawal of subterranean fluids.

SURFACE RUPTURE

During an earthquake, the permanent displacement (or offset) of the earth's surface along a fault plane. Ground breakage at the earth's surface.

TECTONIC

Pertaining to rock structure resulting from deformation of the earth's crust.

TSUNAMI

Earthquake-induced ocean waves, commonly referred to as tidal waves.

WEATHERING

The changes whereby materials such as bedrock decay and crumble to form sediment.